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Competition for traders and risk

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Perverse incentives for banks' traders have played a role in the financial crisis. We study how labor market competition interacts with the structure of compensation to result in excessive risk taking. In a model with trader moral hazard and adverse selection on trader abilities, we demonstrate how banks optimally induce top traders to take more risk as competition on the labor market intensifies, even if banks internalize the costs of negative outcomes. Distorting risk-taking incentives allows banks to reduce the surplus offered to low-ability traders. We find that increasing bank capital requirements does not unambiguously reduce risk taking by top traders.

1. Introduction

■ The financial crisis has been attributed partly to perverse incentives for traders at banks. High bonuses for above-average performance drove traders to engage in riskier trading strategies. Short-term trading gains which in reality were compensation for high downside risk were disguised as profits resulting from above average trader abilities, so it has been argued.¹

Why did banks offer huge bonuses, inducing their traders to take excessive risk? Clearly, one explanation is that banks simply did not internalize the negative effects of risk, being protected by implicit bailout guarantees. In this article, we explore another channel: the role of competition on the labor market for traders in shaping risk-taking incentives from trader bonuses. This analysis is inspired by claims that, even with value-maximizing bank managers, trader compensation could be excessively high powered as a result of strong competition among banks in hiring top traders.²

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¹ See, for instance, Kashyap, Rajan, and Stein (2008) and Clementi et al. (2009).

² Kashyap, Rajan, and Stein (2008) claim that "Retaining top traders, given the competition for talent, requires that they be paid generously based on performance." Clementi et al. (2009) argue for closer cooperation among banks in

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Anecdotal evidence of such competition abounds. In April 2010, Kaspar Villiger, chairman of the Swiss bank UBS, defended the firm's generous pay plans to angry shareholders by saying that an earlier move to cut compensation had backfired. When an entire team of 60 employees had left UBS investment bank's equities unit, he said, "We cut back too much last year, causing us to lose entire teams, their clients and the corresponding revenue."³ When Warren Buffett stepped in at Salomon Brothers in the 1990s after the firm had gotten into trouble, he tried to realign perverse compensation practices. This resulted in defections of top bankers, and eventually a reversal of the reforms. In his statement for the Financial Crisis Inquiry Commission in 2010, Buffett remarked: "I can just tell you, being at Salomon personally, it's just, it's a real problem because the fellow can go next door or he can set up a hedge fund or whatever it may be. You don't, you don't have a good way of having some guy that produces x dollars of revenues to give him 10% of x because he'll figure out, he'll find some other place that will give him 20% of x or whatever it may be." In an article in the *Financial Times*, a banker is quoted saying, "The bonuses are crazy—we all know that. But we don't know how to stop paying them without losing our best staff" (Tett, 2009).

The idea, however, raises an immediate question. It is clear that increased competition for traders raises their expected remuneration. Indeed, such an effect has been found empirically for Chief Executive Officer (CEO) compensation by Bereskin and Cicero (2013), who study a pool of firms competing for the same talent, of which a subset receives a governance shock affecting compensation level. However, it is less clear why the need to leave a larger part of the rents to traders should lead to a different incentive structure. Independent of competition, it would seem that the banks would opt for the incentive structure that leads to highest overall gain, as also observed in Inderst and Pfeil (2013).

We show that competition does increase the risk induced by traders' incentive contracts when there is both trader moral hazard over investment projects and adverse selection on trader abilities. Boustanifar, Grant, and Reshef (2018) show empirically that wages in the financial sector have increased in response to deregulation, and that this effect is stronger in environments where asymmetric information is more severe. Evidence for the fact that traders differ in their trading skills (and that their trading results are not merely a matter of luck) was provided by, for instance, Berk and Green (2004). Banks use compensation schemes both to incentivize traders to choose appropriate investment projects and to attract in particular the top traders. The latter goal is achieved by increasing rewards for top results, which are more easily achieved by top traders.⁴ The downside is that this increases risk profiles sought by these top traders. As competition for top traders increases, the importance of sorting the top traders (and avoiding paying similarly high compensations to traders of average ability) grows, and so the benefit of increasing bonus pay over base wage increases, whereas the costs of inducing the traders to take excessive risks remains unchanged.

We explore this in a model in which two banks compete à la Hotelling in hiring traders. We assume that traders, protected by limited liability, can choose between projects that differ both in expected return and in risk. We consider two types of traders, top traders and average traders. Top traders are better at making high-risk investments than average traders in the sense that their expected payout for such projects is higher. This allows banks to screen on trader type by offering top traders contracts that reward them more strongly for high outcomes. Using this idea, we make the following points. First, when top traders have sufficiently good outside options, the bank has to pay these traders high wages. To prevent those high wages from spilling over to average traders,

revising employee remuneration structure: "Given the fluid market for financial talent, no single firm can get very far on its own."

³ *Financial Times*, "Chastened UBS board promises 'sensitivity,'" April 14, 2010.

⁴ As a compensation consultant, commenting on moves by traders from banks to less-regulated hedge funds, puts it, "Your bonus doesn't fully depend on what your book made, hence the huge amount of turnover, people whose books are making a lot of money and feel they aren't being compensated fairly moving to the buy-side, typically hedge funds or private equity firms" (on news.efinancialcareers.com, August 25, 2017).

the bank pays those wages by offering top traders more high-powered performance contracts. Thus, banks reduce the information rents that need to be paid to average traders by distorting the risk incentives for top traders. The downside is that this results in excessive risk taking by top traders from the banks' point of view.

Second, because in this model, outside options arise endogenously through competition between banks for traders, excessive risk taking by top traders gets worse as competition for such traders intensifies.

We then ask how regulation may help in reducing risk-taking incentives. In the wake of the financial crisis, policy makers across the world have responded by calling for restrictions on traders' bonus payments.⁵ We find that caps on bonuses help to reduce risk taking by traders, increase welfare, but have ambiguous effects on bank profits. On the other hand, increasing the banks' capital requirements does not necessarily resolve the issue that we focus on here. Although stricter capital requirements can align the bank's incentives more closely with society's, we point out that such requirements can actually increase the riskiness of top traders' deals. The intuition is that increasing capital requirements increases banks sensitivity to bad states of the world. However, such outcomes result from projects initiated both by top traders and by average traders. If the latter contribute most to downside risk, the bank will try to lose these average traders to rival banks by decreasing their utility. Because the utilities of the two types of traders are bound together by incentive compatibility, reducing average traders' utility while keeping top traders' utility constant implies increasing risk taking by top traders.

The fact that high-powered incentives can lead to excessively risky behavior has been well established in the corporate finance literature since the seminal contribution by Jensen and Meckling (1976). When corporations issue debt to outsiders, the insiders (managers, entrepreneurs) have strong incentives to exert effort. However, as debt holders share in downside risk but do not benefit from upside potential, such a reliance on only debt financing may induce managers to engage in risk shifting. We show that, even in the absence of risk shifting resulting from the bank's capital structure, internal contracting frictions within banks still cause excessive risk in the privately optimal contracts to top traders: banks increase risk-taking incentives to screen traders.

Our article is related to the literature on optimal contracts when both agents' efforts and risk choices are unobservable. Hellwig (2009) and Biais and Casamatta (1999) consider optimal outside financing for entrepreneurs who have access to a discrete set of projects that vary in both risk and return. Agents hide low effort by choosing projects of higher risk and hence keep the potential for a high return. Second-best optimal contracts then induce higher risks than first-best levels. Palomino and Prat (2003) address the analytically more challenging question of optimal incentive contracts when there is a continuum of projects, each generating a continuum of outcomes (but with different distributions of outcomes). In this article, instead of effort costs, we analyse the existence of adverse selection over agent abilities.

Our second ingredient is competition between principals in the model, which leads to an endogenous reservation wage impacting on the information rents to be left to the low types. The observation that competition on the labor market generates endogenous reservation wages that in turn influence principals' decisions was also made in Acharya and Volpin (2010) and Dicks (2012), in their analyses of externalities in the adoption of tighter corporate governance regimes. Closest to our analysis is an article by Bénabou and Tirole (2016), the Working Paper version of which appeared concurrently with and independently of our own article. Similar to our work, Bénabou and Tirole (2016) study a Hotelling model describing labor market competition among two horizontally differentiated employers, with employees that can be of two types. They find, like we do, that increasing competition leads to overincentivization of the efficient workers. In

⁵ In April 2013, the European Union parliament passed a bonus cap for so-called material risk takers to go into effect in 2014. The cap maximizes the level of variable pay to be the amount of fixed pay. In the United States, section 956 of the Dodd-Frank Act requires disclosure of incentive-based remuneration pay that could lead to material financial loss and prohibits financial institutions from adopting an incentive plan that encourages inappropriate risk.

Bénabou and Tirole (2016), workers are assumed to carry out two tasks, only one of which is contractable. It is the latter one that gets overemphasized as competition grows, at the expense of the noncontractable task. In contrast, our traders carry out only one task, choosing the investment project. We show that competition leads top traders to choose projects featuring excessive risk. A second dimension which distinguishes our article is that we consider whether a change in the banks' objective functions, through increasing capital requirements, can substitute for direct intervention in pay policy.

Related work in the area of principals competing for the (exclusive) services of an agent is by Biglaiser and Mezzetti (1993). They consider two asymmetric principals with different production technologies competing for the services of an agent of unobservable type. Though we look at Hotelling competition between two symmetric principals, the main point of similarity is that the agent's outside option is determined by the contract offer from the competing principal, and that outside option will be type dependent. Jullien (2000) explores the consequences of such type dependent outside options more generally. Closely related are also Schmidt-Mohr and Villas-Boas (1999) and Rochet and Stole (2002) who study screening in a Hotelling competition framework. Rochet and Stole (2002) consider product market competition with different consumer types but no adverse selection. If the whole market is covered for all types, firms offer all types an efficient allocation. Schmidt-Mohr and Villas-Boas (1999), like our model, does feature adverse selection and hence the equilibrium features inefficiency. Schmidt-Mohr and Villas-Boas (1999) focus on how changes in competition affect distortions in contracts offered. Our work adds moral hazard on the part of the agents: screening the agents results in bonus contracts that lead agents to choose projects that deviate from first-best.

Other related recent articles study market failures in compensation setting within banks different from ours and argue for regulation in this area. Inderst and Pfeil (2013) and Thanassoulis (2013) look at benefits and costs of deferral of bonus payments. Besley and Ghatak (2013) analyze how bank bailouts affect trader compensation structures and explore how regulation may be combined with taxation to restore proper incentives. Thanassoulis (2012) looks at the effect of employee remuneration on bank default risk. Banks prefer large bonus components, as these allow efficient risk sharing between bankers and the bank. Increasing competition for traders raises compensation and increases bank default risk. Acharya, Pagano, and Volpin (2016) explore a dynamic model of hidden trader abilities, in which increasing mobility of traders leads to slower revelation of trader types, and incentives for average trader to churn from one firm to another in order to hide their ability to take risk.

Finally, in our model, labor market competition creates an externality among banks, who drive up risk-taking incentives in order to keep good traders on board. On a related note, a fire-sale literature (e.g., Gromb and Vayanos, 2002; Lorenzoni, 2008) identifies an externality among banks through the market for asset prices: in their risk choices, banks do not take into account the (fire-sale) effect of bad outcomes on other banks' investments.

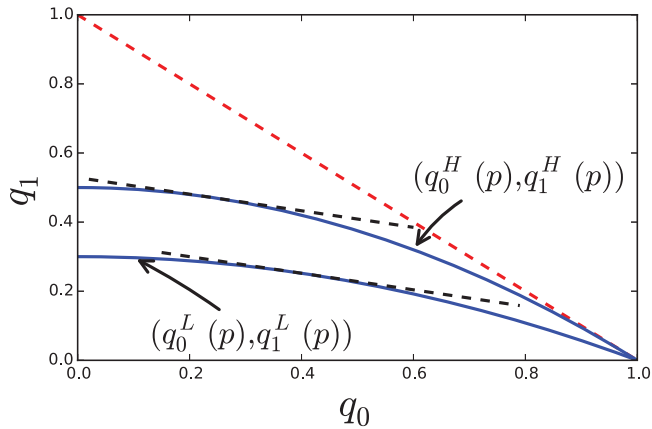
This article is organized as follows. The next section introduces the model for the banks and traders. In Section 3, we characterize the equilibrium in our Hotelling model with competing banks. Section 4 discusses how capital regulation interacts with compensation structures, and argues that direct intervention in wage contracts is called for. Finally, we offer some concluding remarks in Section 5.

2. The model

■ We consider a model of two banks, located at either end of a Hotelling line, which compete in offering labor contracts to traders who are distributed homogeneously along the Hotelling line. There is hidden information: traders differ in abilities to successfully complete an investment project for the bank they are employed by. There is also hidden action: banks cannot observe which project a trader chooses to execute, only the outcome of that project is contractable. The

FIGURE 1

PRODUCTION POSSIBILITY SETS $(q_0^{L,H}(p), q_1^{L,H}(p))$ FOR EACH TRADER TYPE. [Color figure can be viewed at wileyonlinelibrary.com]



banks need to design the labor contract offers to solve both the resulting adverse selection and the moral hazard problems.

In the following, we first discuss the investment technologies for the two trader types, top and average traders. Then, we describe contract design and the banks' objectives.

□ **Projects accessible to traders.** We focus on the following adverse selection problem. Banks face two types of employees: high skill and low skill. The skill lies in the ability to increase the probability of a high payoff for the bank while keeping the variance in payoff in low. The bank uses the wage/bonus structure to separate these types.

We model this as follows. Traders can choose projects p from a set of investment opportunities P . The projects differ both in expected return and in risk. We model this by assuming that all projects yield one of three outcomes,⁶

$$x_1 > x_0 > -x_{-1}.$$

For any project p , the probabilities of each of the three possible outcomes depend on the trader type. Traders can be either of high (H) type ("top traders") or of low (L) type ("average traders"). A fraction ϕ is L trader, $1 - \phi$ is H trader. For a project p , the probabilities of outcomes $x_{1,0,-1}$ are denoted by $q_1^{H,L}(p)$, $q_0^{H,L}(p)$, and $q_{-1}^{H,L}(p) = 1 - q_0^{H,L}(p) - q_1^{H,L}(p)$. Traders' remuneration will depend on realized outcomes, which are observable to the banks. Traders choose projects to maximize their expected remuneration from the bank they are employed by.

The production possibility set P for each trader type is illustrated in Figure 1 in (q_0, q_1) space. The figure plots the frontier $(q_0^j(p), q_1^j(p))$ of the project set P : highest feasible probability q_1 for given middle outcome probability q_0 . We assume that this boundary is decreasing, concave, and smooth.

The intuition behind this description is that banks hire traders that have discretion over the projects (trades) that they engage in. The trader's job is to find investments that have a good risk-return trade-off. This trade-off here is captured by the frontier projects. We assume that each trader type has access to a risk-free project that has $q_0 = 1$. In other words, x_0 denotes the outcome of the risk-free project. When moving away from the risk-free project to $q_0 < 1$, both q_1 and q_{-1} increase. That is, we assume that projects have a higher probability q_1 of exceptionally positive

⁶ We think of the lowest outcome as a loss, in which case, $x_{-1} > 0$.

returns x_1 , but at the cost of a higher risk of losses x_{-1} , $q_{-1} = 1 - q_1 - q_0$. This requires that $\frac{dq_1}{dq_0} > -1$ along the curves. We also assume that $\frac{dq_1}{dq_0} < 0$ everywhere on the boundary, so that a trader always increases the probability q_1 by lowering q_0 .

We say that projects become more risky as q_0 falls. When moving left along the curves, projects also become more risky in the sense that their variance increases.⁷

Furthermore, traders' abilities to generate above-average returns by taking risks differ by types. Top traders (high types) are better at getting a high expected return with low downside, q_{-1} , than average traders (low types). Top traders are those that can best identify trades with great risk-return profiles: they can achieve higher probabilities q_1 of high outcomes x_1 for any given q_0 than average traders do. Average traders are less adept at creating value by moving away from the risk-free project where $q_0 = 1$. Hence, given some value of $q_0 < 1$, their best possible trades will be less profitable compared to the best possible trades a top trader could do at that same level of q_0 . In Figure 1, this means that q_{-1} increases faster (q_1 increases more slowly) with q_0 falling for L traders than for H traders.

The first-best project maximizes the joint payoffs of bank and trader. That is, it solves

$$\max_{p \in P} q_1^j(p)x_1 + q_0^j(p)x_0 - q_{-1}^j(p)x_{-1}. \quad (1)$$

We assume that x_i and $q_i^j(\cdot)$ are such that implementing "the corner solution" project $\arg\max_p q_i^j(p)$ is never optimal for any $i \in \{1, 0, -1\}$, $j \in \{H, L\}$, and therefore restrict attention to an interior optimum. The first-order condition of the optimization problem can be written as

$$-\frac{\frac{\partial q_0^j}{\partial p}}{\frac{\partial q_1^j}{\partial p}} = R^* \equiv \frac{x_1 + x_{-1}}{x_0 + x_{-1}}, \quad (2)$$

where the left-hand side can be interpreted as the marginal rate of substitution of the project set and the right-hand side can be interpreted as a measure of risk. To illustrate, as x_1 increases, joint payoffs increase if the trader invests in more risky projects with higher probability q_1^H : R^* increases. If, instead, x_{-1} increases, it is better to reduce risks by reducing q_1^j and q_{-1}^j : R^* decreases.

In terms of Figure 1, the first-best projects are characterized by the tangent of the lines of constant profit and the trader's project-space boundary.

Though the optimal project will be a different one for the H trader than for the L trader, for either type, the slope of the upper project boundary at the optimal project will be the same. These points are shown in Figure 1 at the tangents to the boundaries (the parallel dashed lines).

□ **The contracts.** A bank offers traders contracts to solve asymmetric information in two dimensions. The bank does not observe the project p chosen by the trader (moral hazard), it only observes realized outcomes. Nor can the bank observe the trader's type (adverse selection). The agent, that is, the trader, knows both his own type and is fully informed on the outcome probabilities $q_i^{H,L}(p)$ ($i \in \{-1, 0, 1\}$) associated with each project p .

A bank offers both H and L traders take-it-or-leave-it contracts, specifying remunerations contingent on observed outcomes x_{-1} , x_0 and x_1 , which the traders then accept or reject. We assume that traders have limited liability, so that wages under any outcome are nonnegative. We parametrize these remunerations as a fixed transfer t^H, t^L in the contract targeted at H , resp., L traders, plus bonus payments for either trader type, w_1^H, w_1^L , and w_0^H, w_0^L for the high x_1 and average x_0 outcomes. Limited liability restricts $t^j, t^j + w_i^j \geq 0$ for $j \in \{H, L\}$, $i \in \{0, 1\}$.

⁷ The derivative of the variance $q_0(x_0 - \bar{x})^2 + q_1(x_1 - \bar{x})^2 + (1 - q_0 - q_1)(-x_{-1} - \bar{x})^2$ is larger than zero for $0 \leq \frac{\partial q_1}{\partial q_0} \leq 1$ if $x_0 < x_1$; where \bar{x} denotes the mean return.

Given these wages, a trader of type j chooses the project p that optimizes their expected utility,

$$u^j = \max_p q_1^j(p)w_1^j + q_0^j(p)w_0^j + t^j. \quad (3)$$

In words, the bank cannot contract on p directly (moral hazard). To implement a certain project p , the bonuses w_i^j need to be set so as to make it incentive compatible for the trader to choose this project. In particular, project choice is determined by the bonus ratio in the contract, which we define as

$$r^j = \frac{w_1^j}{w_0^j}$$

if $w^j \neq 0$.

If $w_1^j = w_0^j = 0$, trader j gets the outcome-independent fixed wage t^j and is indifferent over project outcomes. In this case, we assume him to choose the project that maximizes the bank's profits. Also, we define r^j to be equal to R^* in that case.

A larger r^j leads the j trader to place a higher weight on the probability of high outcomes x_1 , relative to average outcomes x_0 . In that case, maximum trader utility (3) is attained at a lower value of q_0 , and a higher value of both q_1 and q_{-1} . Higher r^j thus lead traders to choose projects with higher probability of extreme outcomes, and lower probability of an average outcome. In this sense, we identify higher bonus ratios with higher project risk.

In what follows, it is convenient to characterize contracts in terms of the bonus ratio r^j , which governs the trader's choice of project, and the expected utility u^j the contract offers to the trader, instead of the bonus payments w_i^j along with the fixed payment t^j . Thus, (r^j, t^j, u^j) refers to j 's contract where the combination of wages (w_0^j, w_1^j, t^j) satisfies:

$$u^j = \max_p w_0^j (q_0^j(p) + r^j q_1^j(p)) + t^j.$$

Let $p^j(r^j)$ denote the project p that solves j 's maximization problem.

□ **Bank competition for traders.** We model labor market competition among banks (the principals) for traders (the agents) by using a Hotelling model. We consider a Hotelling beach of length 1 where L and H traders are distributed uniformly with density ϕ and $1 - \phi$, respectively. Two symmetric banks, a and b , are located on the far left and right of the beach. Traders face a travel cost per unit distance equal to τ^L for the low type and τ^H for the high type. In this case, bank a 's shares of traders of either type is governed by the difference in utilities, $u_a - u_b$, offered to each type:

$$s^L(u_a^L, u_b^L) = \phi \left(\frac{1}{2} + \frac{u_a^L - u_b^L}{2\tau^L} \right), \quad s^H(u_a^H, u_b^H) = (1 - \phi) \left(\frac{1}{2} + \frac{u_a^H - u_b^H}{2\tau^H} \right), \quad (4)$$

where we allow the competition parameters $\tau^{L,H}$ to depend on trader type.

The parameter $\tau^j > 0$ captures that traders do not all switch banks because one bank pays a bit more than the other. Other factors play a role as well; a trader may like his colleagues, one bank may be closer to his home, reducing commute time, etc. In general, $1/\tau^L$ and $1/\tau^H$ capture how aggressively banks compete for L and H traders, respectively.

In our context of banks' traders, one can interpret travel costs τ^j literally: banks a and b are in different countries and workers face a cost to relocate. One can argue that in the past decades, globalization has increased competition for traders between banks internationally. Indeed, Boustanifar, Grant, and Reshef (2018) find that high wages in finance succeed in attracting skilled workers across borders. If we assume that top traders migrate more easily, say from London to Hong Kong, than average traders, then this international competition has decreased τ^H more than τ^L . Below, we analyze the effect of a fall in τ^H for given τ^L .

The j trader who is indifferent between working for either bank is a distance x away from bank a and $1 - x$ from b , where x solves

$$u_a^j - \tau^j x = u_b^j - \tau^j (1 - x).$$

With full coverage (as we shall assume), this gives the expression for bank a 's market share $s^j(u_a^j, u_b^j)$ of type j traders above.

Banks choose contract offers to maximize their total expected net profits. Bank net profit from a trader of type j equals the sum of expected gross profits from the project undertaken by the trader, minus the utility left to trader type j . From equation (1), we write gross profits as

$$\pi^j(r^j) = q_1^j(p^j(r^j))(x_1 + x_{-1}) + q_0^j(p^j(r^j))(x_0 + x_{-1}) - x_{-1}. \quad (5)$$

To get the bank's net profits from type j traders, we subtract the expected utility left to type j , u^j . Bank a 's total profits equal net profits per trader-type, multiplied by the shares of each type employed by the bank,

$$\Pi_a = s^L(u_a^L, u_b^L) (\pi^L(r_a^L) - u_a^L) + s^H(u_a^H, u_b^H) (\pi^H(r_a^H) - u_a^H).$$

Taking trader utility u^j as given for a moment, the optimal projects from the point of view of the bank coincide with the first-best. That is, profits are maximized for projects on the project boundary (q_1^j, q_0^j) with slope

$$-\frac{dq_1^j}{dq_0^j} = 1/R^* < 1, \quad (6)$$

where first-best R^* is defined in (2). In that case, gross profits from this trader's project equal $\pi^j(R^*)$.

Throughout the analysis, we assume τ^L, τ^H to be sufficiently low compared to profits so that in equilibrium, all traders accept a contract, that is, the Hotelling beach is fully covered. To assure that this happens in equilibrium, and that full coverage also obtains if one of the banks deviates, we make the following assumption on the magnitude of travel costs τ^j relative to gross profits π^j .⁸

Assumption 1. $\pi^L(R^*) > 2\tau^L, \quad \pi^H(R^*) > 2\tau^H.$

□ **Incentive compatibility.** Let us now focus on the traders' project choice. Trader j , in response to a bonus ratio r^j , opts for the project on the project boundary where

$$-\frac{dq_1^j}{dq_0^j} = \frac{1}{r^j}, \quad (7)$$

or on an extremal point corresponding to $q_0 = 0$ ($q_0 = 1$) for a bonus ratio sufficiently high (low). Hence, without asymmetric information about trader type, the bank can fully resolve moral hazard on project choice. By setting $r^j = R^*$, the bank induces traders to choose the bank's optimal project.

This will not necessarily be optimal though, when trader types are hidden. In that case, contracts have to respect incentive compatibility (IC) with respect to the traders' type revelation. We use IC to refer to type revelation/adverse selection (not to moral hazard with respect to project choice p in (3)).

⁸ To see why this assumption implies full coverage, consider the case where the indifferent trader x is given by $\tau x = u$ if the bank offers u . This reflects a situation without a competing offer by the rival bank. The bank then solves

$$\max_u \frac{u}{\tau} (\pi - u).$$

It is routine to verify that $\pi \geq 2\tau$ implies that the bank would also like to employ a trader at maximum distance 1 away: full coverage.

Consider first L 's IC constraint. When confronted with the (w_0^H, w_1^H) compensation contract, L chooses the project that, given bonus ratio r^H , optimizes his own payoff. The L trader's utility \hat{u}^L from accepting the H contract (mimicking H) is given by

$$\hat{u}^L = \max_p w_0^H (q_0^L(p) + r^H q_1^L(p)) + t^H.$$

As the utility-maximizing project for either type depends only on r^H , we see that the ratio of L 's utility from bonus payments upon accepting the H contract, $\hat{u}^L - t^H$, and H 's expected utility from bonus payments from the same contract, $u^H - t^H$, depends only on r^H . We denote this ratio

$$f(r^H) \equiv \frac{q_0^L(p^L(r^H)) + r^H q_1^L(p^L(r^H))}{q_0^H(p^H(r^H)) + r^H q_1^H(p^H(r^H))} = \frac{\hat{u}^L - t^H}{u^H - t^H} \leq 1.$$

Because L cannot get more utility from a compensation contract than H , who has superior success probabilities for any bonus ratio r^H , we have $f(r^H) \leq 1$ and $f(0) = 1$.

Trader L 's IC condition thus amounts to

$$u^L \geq \hat{u}^L = (u^H - t^H)f(r^H) + t^H. \quad (8)$$

In order to solve the bank's screening problem below, we follow the literature and assume that single-crossing is satisfied. In our trader model, this means that if banks increase the bonus w_1 for the high outcome (keeping t and w_0 constant), top traders benefit more than average traders, as they are better able to find projects with higher upside—without increasing too much the probability of negative outcomes—than average traders are.

In technical terms, we assume that when both types' indifference curves intersect in (w_0^j, r^j) -space, the curve for H is less steep than the curve for L . Note that this condition for single-crossing is not quite standard, as for each combination w_0^j, r^j , the agent maximizes over p . The indifference curve is of the form

$$\max_p \{w_0^j(q_0^j(p) + r^j q_1^j(p)) + t^j\} = \text{constant}. \quad (9)$$

The slope of this indifference curve in (w_0^j, r^j) space is given by

$$\frac{dr^j}{dw_0^j} = \frac{-1}{w_0^j} \left(\frac{q_0^j(p)}{q_1^j(p)} + r^j \right). \quad (10)$$

Hence, to get single-crossing, we make the following assumption.

Assumption 2. For each r , we assume that

$$\frac{q_1^H(p^H(r))}{q_0^H(p^H(r))} > \frac{q_1^L(p^L(r))}{q_0^L(p^L(r))}. \quad (11)$$

The interpretation of single-crossing in this context is the following. Combining (10) and (11), H 's indifference curve in w_0, r space is flatter than L 's indifference curve, whenever they intersect. That is, a given increase in r leads to a bigger increase in utility h , and therefore a bigger fall in w_0 —to keep utility constant—for H than for L , because H 's trading talent makes him benefit more from the high w_1^H . In terms of Assumption 2: if both types choose their optimal project for a given bonus ratio r , the H -type has a higher probability ratio q_1/q_0 than the L -type. Put differently, H is relatively more likely to generate the high payoff x_1 compared to the average payoff x_0 . Hence, single-crossing captures that H is more talented and therefore better able to exploit a high bonus ratio w_1/w_0 .

It follows from Assumption 2 that $f'(r) < 0$. This can be seen as follows. Using an envelope argument with respect to p , we find that

$$f'(r) = \frac{q_1^L(q_0^H + rq_1^H) - q_1^H(q_0^L + rq_1^L)}{(q_0^H(p^H(r)) + rq_1^H(p^H(r)))^2} < 0. \quad (12)$$

Thus, we have $f(0) = 1$, $f(r) \geq 0$, and $f'(r) < 0$. To allow us to focus on first-order conditions, we also assume that $f(r)$ is convex,

Assumption 3. $f''(r) \geq 0$.

As $f(r)$ is given by $\hat{u}^L - t^H = f(r)(u^H - t^H)$, we can write $\frac{\partial^2 \hat{u}^L}{\partial r^2} \big|_{u^H} = (u^H - t^H)f''(r)$. As we show below, $w_0^j, w_1^j \geq 0$ and hence, Assumption 3 implies $\frac{\partial^2 \hat{u}^L}{\partial r^2} \big|_{u^H} \geq 0$: there are decreasing returns for the bank of using risk r to separate types.

Consider next H 's IC condition. Following a similar argument as in the case of an L trader, an H trader's utility, when he chooses the L contract, equals $\hat{u}^H = (u^L - t^L)/f(r^L) + t^L$. Thus, we find that H 's incentive-compatibility condition is

$$u^H \geq \hat{u}^H = \frac{u^L - t^L}{f(r^L)} + t^L. \quad (13)$$

□ **Traders' outside options.** We make the natural assumption that, in the absence of adverse selection over trader types, H -type traders obtain a larger remuneration u than L -type ones. Without adverse selection, banks could simply pay fixed wage contracts, and traders do the optimal projects, leading to profits $\pi^H(R^*)$ and $\pi^L(R^*)$. Standard Hotelling competition between the banks results in the following well-known utilities for the L -type and the H -type traders (gross of their travel costs),⁹

$$u^{L*} = \pi^L(R^*) - \tau^L, \quad (14)$$

$$u^{H*} = \pi^H(R^*) - \tau^H. \quad (15)$$

In words, of total profits π^* , traders get u^* and banks $\pi^* - u^* = \tau$. Hence, the more competitive the market for traders (the lower τ), the more banks compete away rents to the benefit of traders. Our assumption then amounts to

Assumption 4. $\pi^L(R^*) - \tau^L < \pi^H(R^*) - \tau^H$.

This holds, for instance, if the H -trader market is at least as competitive as the L -trader one, $\tau^H \leq \tau^L$. For our question, this is the interesting regime. Assumption 4 will imply that, in our model, the H trader's incentive-compatibility constraint is slack.

Finally, we are interested in equilibria in which screening is possible. In first-best, incentive compatibility for the low types obtains if $f(R^*)u^{H*} \leq u^{L*}$ holds. Participation constraints will not bind due to the full-coverage Assumption 1.

If, on the other hand, $f(R^*)u^{H*} > u^{L*}$, the low trader's IC constraint will be binding in equilibrium.¹⁰ Consequently, banks will distort H traders' contracts to prevent the L traders from mimicking. Our final assumption on the competition parameters guarantees that banks can use r^H to separate the two types in this case.

⁹ See Tirole (1988).

¹⁰ It is easy to see that if, instead, high-type incentive compatibility were binding, $u^L = u^H$, a bank could always improve profits by either slightly raising u^H or slightly lowering u^L , making both IC constraints slack.

Assumption 5. For some $\bar{r}^H > R^*$ large enough, $f(\bar{r}^H)(\pi^H(\bar{r}^H) - \tau^H) < \pi^L(R^*) - \tau^L$. Also, $\bar{r}^H < -(\frac{dq_0^H}{dq_0^L})^{-1}|_{q_0^H=0}$.

This assumption implies that bonus ratio r^H can be used to separate types: there exists a level r^H high enough such that L does not want to mimic H , who receives $\pi^H(\bar{r}^H) - \tau^H$. Basically, we make the natural assumption that as r^H increases, either $f(r^H)$ or $\pi^H(r^H)$ becomes sufficiently low that Assumption 5 holds. The second part of the assumption allows us to avoid corner solutions where $q_0^H = 0$, and raising r^H has no further impact on the project undertaken by the H trader.

In the next section, we show that, when faced with IC constraints from adverse selection, the banks may resort to a distortion in H 's bonus ratio r^H to values exceeding R^* , inducing H traders to pursue higher risk projects than socially optimal. The extent of this distortion depends on the endogenous outside option resulting from imperfect competition for traders among the two banks.

3. Analysis

■ To analyze the equilibrium contract menu offers by the two banks, we first show that we can restrict attention to contracts that have no fixed wage part for high-type traders, and only a fixed wage for the low types.

Lemma 1. It is optimal to offer H a full bonus contract with $t^H = 0$ and $w_{0,1}^H \geq 0$, and to offer L a fixed rate contract, with $t^L = u^L$ and $r^L = R^*$.

In order to prevent L from mimicking H , the bank pays H using bonus payments only (no fixed rate). As H is better at generating returns, these bonus payments make the H contract unattractive for the L -type. Indeed, as $f(r) \leq 1$ in the low type's IC constraint (8), shifting payments from t^H to bonus payment $u^H - t^H$ relaxes the constraint. Exactly because H is the better trader, the incentive to mimic L is reduced by setting $w_{0,1}^L = 0$. The high type's IC (13) is more easily satisfied if we shift payment from bonus $u^L - t^L$ to fixed payment t^L . As L is indifferent, he chooses the project that maximizes the bank's payoff, and, as previously stated, we define $r^L = R^*$ in this case.

We can now turn to the analysis of the optimal contracts in our Hotelling model. Bank a optimizes its profits given the contract offered by bank b , subject to the two IC constraints for the traders. Using Lemma 1, we can write bank a 's optimization program as:

$$\begin{aligned} \max_{u^L, r^L, u^H, r^H} \quad & s^L(u^L, u_b^L)(\pi^L(r^L) - u^L) + s^H(u^H, u_b^H)(\pi^H(r^H) - u^H) \\ \text{s.t.} \quad & u^L \geq u^H f(r^H) \\ & u^H \geq u^L, \end{aligned} \quad (16)$$

where $s^L(u_a^L, u_b^L)$ represents bank a 's share of L traders, as in equation (4), when bank a offers them utility u_a^L and bank b offers u_b^L . By our full-coverage Assumption 1, we can ignore participation constraints and we have inelastic total supply of traders, so that $s^L(u_a^L, u_b^L) + s^L(u_b^L, u_a^L) = \phi$, where $\phi \in (0, 1)$ denotes the share of L traders. Similar remarks hold for H 's shares: $s^H(u_a^H, u_b^H) + s^H(u_b^H, u_a^H) = 1 - \phi$.

The first part of the maximand in (16) represents bank a 's net gains from L 's activities. The second component reflects H 's contribution to the bank's profit. For bank b , symmetric expressions apply. As we focus on symmetric equilibria, both banks evenly share the number of H as well as L traders in equilibrium. The first constraint is L 's IC condition, in which we use $t^H = 0$ from Lemma 1. The second is H 's IC condition (with $t^L = u^L$).

The characterization of the symmetric equilibrium hinges on whether incentive compatibility is binding in first-best. Note first that, from Assumption 4, H -type traders get more rents in an environment with symmetric information. Consequently, the H -types' IC will not bind. We can therefore identify two regimes, depending on whether the L -types' IC binds in first-best or not, as follows:¹¹

Proposition 1. For given τ^H, τ^L ,

- if $f(R^*)(\pi^H(R^*) - \tau^H) \leq \pi^L(R^*) - \tau^L$, then banks offer contracts such that $r^L = r^H = R^*$;
- if $f(R^*)(\pi^H(R^*) - \tau^H) > \pi^L(R^*) - \tau^L$, then banks offer contracts such that $r^L = R^*$ and $r^H > R^*$.

In the first case, first-best is realized. Although an H -type gets higher utility, $u^{H*} = \pi^H(R^*) - \tau^H$, than an L -type (who receives $u^{L*} = \pi^L(R^*) - \tau^L$), the wedge between the two is not too large. The bank offers separating contracts where the L trader receiving u^{L*} does not want to mimic H (this is what $u^{H*} f(R^*) \leq u^{L*}$ means). There is no reason to distort r^H in this case. Neither does H want to mimic L , so that r^L is not distorted either. Following Lemma 1, the L -types get a fixed wage $t^L = u^{L*}$, and by assumption execute the bank-optimal contract. H -types obtain a contract consisting only of bonus payments, with optimal bonus ratio $r^H = R^*$.

In the second case, the ratio of first-best utilities u^{H*}/u^{L*} is so high that an L -type being offered utility u^{L*} would like to mimic H , as $f(R^*)u^{H*} > u^{L*}$. To separate the types, the bank will distort $r^H > R^*$ to make it harder for L to mimic H . The intuition is that, as L is not so apt at taking risks, setting $r^H > R^*$ reduces L 's utility from the bonus contract offered to H . In other words, to prevent the high wages offered to H from spilling over to L , the preferred choice is to offer them in the form of bonuses on good outcomes x_1 , which are more valuable to H than to L . The cost of doing so, for the bank, is that these wages induce H to execute suboptimal projects.

As these first-best utilities depend on the competition parameters $\tau^{H,L}$, the crucial consequence of Proposition 1 is that banks induce inefficiently high risk taking for H traders if the H labor market is sufficiently competitive: given τ^L , the distortion in the high-types' bonus ratio r^H emerges for τ^H low enough. In that case, the value of the H traders' rents is sufficiently high relative to the L traders'.

We are interested in comparative statics in τ^H in the case where competition for H traders is so intense that banks induce inefficient risk taking by these traders. That is, we focus on the case where $f(R^*)(\pi^H(R^*) - \tau^H) > \pi^L(R^*) - \tau^L$.

As explained in the proof of Proposition 2 in the Appendix, multiple symmetric equilibria cannot be ruled out in this case. If multiple equilibria exist, we make the following two assumptions to deal with this: (i) $\pi^H(r^H)$ is concave in r^H and (ii) banks coordinate on the symmetric equilibrium which maximizes the sum of their profits. We know from Lemma 2 in the Appendix that $\pi^H(r^H)$ is quasiconcave in r^H ; assumption (i) is (a bit) more restrictive than this. Assumption (ii) implies that banks play the coalition proof equilibrium.

Our second result is that banks incentivize top traders to take more risk as competition for top traders intensifies, that is, the risk problem becomes worse as τ^H falls.

Proposition 2. Banks induce H traders to take more risk by increasing r^H as competition for H traders increases (τ^H falls).

The intuition for this result is, that, as τ^H falls, H traders switch banks more easily to increase their income. In that case, banks experience stronger gains to increasing H traders' wages u^H to win them over, at the expense of the rival bank. In the symmetric equilibrium, banks do not

¹¹ We need to add some additional technical assumptions to make sure the symmetric equilibrium exists; in particular, ruling out deviations in which one firm either takes all agents in the markets (cornering) or abandons one type of trader completely to its rival (exclusion). We explore sufficient conditions for this in Appendix B.

benefit from this race to offer higher wages to the H trader. To the contrary, IC also forces banks to increase wages for L traders. In an attempt to keep this leakage of rents to L traders low, banks raise r^H : the marginal benefits to raising r^H increase, whereas the marginal costs (in terms of less-efficient projects initiated by the H trader), remain the same.

4. Policy implications

■ In the wake of the financial crisis, there has been much debate on curtailing bankers' bonuses, in a bid to reduce bank risk taking. Whereas the benefits of reducing top executives' risk appetites are little disputed, the desirability of intervention in wage contracts lower in the bank hierarchy might be less obvious. If bank management internalizes the risk of negative outcomes, for example, through higher equity stakes in the bank, one might be tempted to argue that their risk attitudes trickle down to the lower trader echelons through the contracts these are offered.

In this section, we point out that this view should be qualified, by looking at two implications of our model. First, direct intervention in wage contracts helps to reduce excessive risk taking. Second, leverage restrictions on the banks (the principals) do not necessarily alleviate excessive risk taking by traders (the agents).

□ **Wage contract intervention.** We first consider a bonus cap policy, in which a regulator limits risk taking incentives by imposing a cap \bar{R} on bonus structure that binds for the high-type trader, so that $r^H = \bar{R}$. We assume that the cap \bar{R} is larger than the first-best bonus structure R^* . We are interested in both total welfare, and in the distributional effects of changing the cap \bar{R} .

We assume both banks compete for traders and will both be subject to the same regulation. Total welfare is given by the sum of bank profits and trader utility $W = \phi\pi^L(R^*) + (1 - \phi)\pi^H(r^H)$. Thus, the effect on welfare is simply the effect of r^H on $\pi^H(r^H)$, wages being transfers.¹² If the cap is binding, $r_H = \bar{R}$, a reduction in \bar{R} brings bonus structure closer to the socially optimal value of R^* .

The distributional effects of reducing a binding regulatory bonus cap are more ambiguous. On the one hand, lowering the industry-wide cap \bar{R} makes it harder to screen low-type traders, and a larger leakage of rents from high to low types takes place, making banks more reluctant to pay for top talent. On the other hand, the competitive externality among both banks led them to raise bonus structure R excessively, harming profits from the top type in a bid to shed low-type traders to their rival. Capping r^H reduces this competitive externality, increasing profits from the high-type sector, which makes it more attractive for banks to compete for these types. Depending on the size of lost profits due to excessive risk taking, either effect can dominate.

Proposition 3. A reduction in the binding bonus cap $\bar{R} \geq R^*$, leads to:

- increased total welfare,
- higher utility for low-type traders,

whereas the effect on high types and bank profits can go either way.

Should we expect banks to introduce such wage measures voluntarily? Clearly, one bank will not find it profitable to introduce bonus caps unilaterally. A bank could choose a lower r^H itself but this is not optimal. For given u^H , a lower r^H would force the bank to increase u^L , which is costly; or it would force the bank to reduce u^H , which reduces its market, share on the H market, which is not profitable either.

Should we then expect banks to lobby the government to introduce bonus regulation? In our closed economy duopoly, the model predicts that banks might lobby for such an intervention, if indeed the profit loss from the competitive externality, imposing excessive risk on the high types,

¹² Assuming we continue to have full coverage for both types.

is large. In an internationally competitive market such as banking, having one country regulating bonuses is not beneficial for its home banks. They will lose H traders to banks in other countries. Hence, bonus regulation can only be profitable for banks if it happens on a global scale.

From the country's perspective, it can still be welfare enhancing to introduce bonus regulation. The trade-off for the government is then higher efficiency due to less risk taking by traders, versus making home banks less attractive for top traders.

Taxing traders' pay is an alternative policy to address excessive risk taking. If traders only receive a fraction $1 - \theta$ of the utility paid to them by their employers (where θ denotes the marginal tax rate), the banks' profit functions change: the fraction of traders attracted by bank a now depends on $(1 - \theta)(u_a^H - u_b^H)$. As can be seen from the Hotelling specification, (4), this effectively increases the travel cost τ^H , muting labor market competition among banks and reducing the competitive externality. As a result, equilibrium r^H will be reduced.

Summarizing, directly intervening in the traders' wage structure is an effective policy for governments to reduce risk taking. As discussed in the Introduction, this finding is in line with Bénabou and Tirole (2016). However, in our context of bank regulation, it has been argued that changing banks' objective functions is a better way to reduce excessive risk taking. In particular, the argument goes, forcing banks to hold more equity—reducing leverage—so that they stand to lose more in case of bankruptcy will lead banks to reduce bonuses and hence risk taking. We investigate this next.

□ **Leverage restrictions.** We argue that with excessive bonuses due to competition between banks for top traders, direct intervention in the wage structure can be more effective in reducing risk than increasing banks' equity. We make this point by going through an example where one role of the bonus—separating trader types—is emphasized. In this example, increasing equity requirements for banks actually increases risk taking. The point of the example is to illustrate this counterintuitive effect, which reduces the effectiveness of leverage restrictions. We do not claim that this effect always dominates in the real world.

To see this effect, let E denote the bank's equity. With equity taken into account, we can write the bank's gross profit (5) from trader type j as

$$q_1^j(x_1 + E) + q_0^j(x_0 + E) + q_{-1}^j \max\{E - x_{-1}, 0\} - E, \quad (17)$$

with $j = H, L$. Positive profits from the project are added to existing equity, losses are paid out of equity but up to the point of the bank's liability that is limited to available equity. We assume that the bad state is so "catastrophic" that $E - x_{-1} < 0$ for the values of E that we consider. Then, we can write this gross return as

$$q_1^j x_1 + q_0^j x_0 - q_{-1}^j E. \quad (18)$$

The higher the bank's equity stake E , the more the bank loses in the bad state. More generally, going bankrupt has negative external effects on debt holders and the government—in case the government pays for a bailout. Due to the rise in E , the bank internalizes more of these external effects. The bank's objective and the social objective get better aligned.

By comparing equations (5) and (18), we see that changing E is equivalent to doing comparative statics with respect to x_{-1} . Hence, in our model, the question becomes: does increasing x_{-1} lead to lower r^H and hence less risk taking by top traders?

At first sight, it seems intuitive that raising x_{-1} reduces a bank's preference for risk and hence reduces r^H . Indeed, this can happen in our model. However, this is not necessarily the case due to the fact that r^H plays two roles: (i) it affects top traders' preference for risk (moral hazard) and (ii) it separates H - and L -types (adverse selection). In the latter role, an increase in x_{-1} can raise r^H .

The intuition for this is as follows. An increase in x_{-1} increases the bank's aversion to negative outcomes in the bad state. Negative outcomes result both from H projects, and from those of L traders. If the latter create the larger downside risk, banks tend to reduce L 's utility

u^L in an effort to lose L traders to the rival bank as x_{-1} increases. They will do so by increasing r^H if this is not too costly (and it will not be costly if an H -type's project choice is rather inelastic with respect to r^H). In this way, banks impose a competitive externality on each other. In equilibrium, banks do not succeed in shedding L traders; both banks continue to share L traders evenly, so the increase in H 's risk r^H does not help them to reduce exposure to L 's downside risks.

To formalize this intuition, we consider the case where only the second role of r^H —separating types—plays a role. We assume that H traders are completely inelastic with respect to r^H . Say, there is an obvious best project—irrespective of r^H —that H traders can identify but L traders cannot.¹³ This is extreme, but by continuity, the result also holds for the case where H traders are rather—but not fully—inelastic with respect to r^H , and raising r^H does lower the value of the H -type's project.

The assumption implies that $\pi_r^H = 0$ and hence, both u^L and u^H can be set at their first-best values given by equations (14) and (15). Indeed, because $\pi_r^H = 0$, IC issues can be resolved with r^H at no cost and hence, there is no reason to distort u^L , u^H . Using that $u^L = f(r^H)u^H$, the first-order conditions for u^H and r^H can be written as

$$u^H f(r^H) = \pi^L(R^*) - \tau^L \quad (19)$$

$$u^H = \pi^H(r^H) - \tau^H. \quad (20)$$

Combining these two equations, we find

$$(\pi^H(r^H) - \tau^H) f(r^H) = \pi^L(R^*) - \tau^L.$$

From this equation, we can evaluate the dependence of r^H on x_{-1} ,

$$\frac{dr^H}{dx_{-1}} = \frac{\pi_{x_{-1}}^L - \pi_{x_{-1}}^H f(r^H)}{f'(r^H)(\pi^H(r^H) - \tau^H)},$$

where

$$\pi_{x_{-1}}^L = -q_{-1}^L < 0, \quad \pi_{x_{-1}}^H = -q_{-1}^H < 0.$$

If, in the optimum, L 's probability of the bad state, q_{-1}^L , is larger than H 's probability, we find $\frac{dr^H}{dx_{-1}} > 0$, that is, H 's bonus ratio increases with x_{-1} . As mentioned, the example of fixed project choice is extreme, but the analysis continues to hold if H 's probabilities, $q_{1,0,-1}^H(p(r^H))$, change sufficiently slowly with r^H , so that $d\pi^H/dr^H$ is small in equilibrium. Summarizing, we have shown the following.

Proposition 4. When banks compete for traders, an increase in equity requirements can increase, rather than decrease, risk in H 's equilibrium contract, $\frac{dr^H}{dx_{-1}} > 0$.

As mentioned, our claim is not that equity requirements always increase risk taking. Indeed, there is the moral hazard effect which leads the bank to reduce r^H in response to an increase in E , as one would expect. However, the adverse selection effect moves in the opposite direction, making this measure less effective than one would expect if L traders are at least as likely to trigger the bad state as H traders. Ultimately, it is an empirical question whether bank failures are either caused by top traders taking calculated risks or by less-talented traders making huge mistakes.

We conclude that measures aimed at reducing bank risk only at the top of the bank hierarchy may have unintentional effects on the risk attitudes of individual bank traders. These effects result

¹³ In Figure 1, this might be represented by a kink in the high type's boundary curve.

from a combination of agency problems within the banks, and spillover effects mediated through competition on the labor market among banks. Directly regulating bonus pay also at lower bank levels can therefore be a useful complement to measures regulating bank risk at the top levels.

5. Concluding remarks

■ We provide a model rationalizing the claim that increased competition for traders forces banks to execute riskier deals. The mechanism for excessive risk taking we describe here is different from the usual one, where banks fail to fully internalize the losses. In the present model, even if banks fully internalize the costs of negative outcomes, banks offer traders excessively risky contracts to screen on trader type and to minimize transfers to lower skilled employees.

We have two main results. First, banks offer riskier contracts (higher bonus ratio r^H) as competition for top traders intensifies (τ^H falls). When competition increases, the rents banks have to pay to attract top traders increase. To avoid leakage of these rents to average traders, the higher payment comes in the form of contracts paying larger bonuses and hence, inducing more risk taking by top traders.

Second, caps on bonuses mitigate the adverse welfare effects we identify. In contrast, raising capital requirements does not necessarily result in banks offering traders contracts that reduce risk taking. If average traders create more downside risk than top traders, banks that are confronted with a higher liability for losses may increase r^H in an effort to lose the lower-skilled traders to rival banks: higher r^H will reduce these traders' utility. Consequently, bonus payments to top traders will not automatically decrease when higher capital requirements force banks to internalize a larger fraction of potential losses.

Although a regulator faces the same adverse selection over trader types as the banks do, a planner will not resort to inefficient screening by offering excessive incentives. The reason is that whereas banks distort production to change the distribution of profits among themselves and the traders, for the regulator, these payments are pure transfers.¹⁴ Therefore, there is a role for direct intervention in compensation structures, aimed at reducing trader incentives toward risk taking.

This leaves the question *why* competition over skilled traders should have increased in the buildup to the present financial crisis. One explanation could be that competition in financial institutions' product markets intensified as well. As firms face stiffer competition in attracting clients, a competitive advantage becomes more valuable, and top traders may provide such an advantage. The competition over traders in our model would, in that case, be a reduced form of competition in product markets.

Appendix A

This appendix contains the proofs of Lemma 1 and propositions 1, 2 and 3.

Proof of Lemma 1. First, note that we can focus on contracts that have $w_i^j \geq 0$ for $i = 1, 0$, $j = H, L$. To see this, we write a bank's net profits from trader j as

$$q_1^j(p)(x_1 - w_1^j) + q_0^j(p)(x_0 - w_0^j) - q_{-1}^j(p)x_{-1} - t^j = \pi^j - u^j. \quad (\text{A1})$$

Hence, for given value of u^j , there is no benefit in rent distribution for the bank in distorting bonuses w_i^j ; for example, choosing negative bonuses compensated by higher t^j . So, we need to check whether there are beneficial incentive effects of setting $w_i^j < 0$.

If both w_1^j and w_0^j were to be chosen negative, the trader would choose the (interior) project which fails surely, $q_{-1} = 1$; $q_0 = q_1 = 0$, an outcome that is never optimal for the bank. If, say $w_1^j < 0$ and $w_0^j \geq 0$, the trader would avoid risky projects and maximize his utility by choosing the safe project with $q_0 = 1$. The same outcome would be realized with $w_1^j = 0$; hence, we can focus on $w_1^j \geq 0$ without loss of generality. A similar argument holds if $w_0^j < 0$ and $w_1^j \geq 0$.

Next, on inspection of both IC constraints, noting that $f(r) \leq 1$, L 's IC constraint (8) is relaxed if we shift H income from fixed component t^H to bonus component $u^H - t^H$. As the agents are risk-neutral, we can restrict our analysis

¹⁴ In our stylized model, aggregate trader supply is completely inelastic. When supply of traders is elastic, the regulator will be concerned about the level of trader utility, but not to the degree that a bank is.

to H contracts that pay out fully in terms of bonuses, that is, $t^H = 0$. Vice versa, H 's IC constraint (13) is relaxed by shifting weight away from bonuses, toward the fixed component. Because $w_{0,1}^L \geq 0$, we can therefore choose $u^L = t^L$, set bonuses $w_{0,1}^L = 0$, and allow the bank to specify L 's project to be the first-best one. In this case, we define $r^L = R^*$. ■

Proof of Proposition 1. We first show that net profits $\pi^j(r^j)$ for either type are maximized at the solution of the first-order equation, $r^j = R^*$. This is implied by the following lemma:

Lemma 2. The function $\pi^j(r^j)$ is quasiconcave in $r^j \geq 0$.

Proof of Lemma 2. For any given $r^j \geq 0$, j chooses the project on the project boundary $q_1^j(q_0^j)$ that satisfies $\frac{dq_1^j}{dq_0^j} = -\frac{1}{r^j}$. This relation defines a function $q_0^j(r^j)$ with $dq_0^j/dr^j \leq 0$. From equation (5), we can then compute

$$\begin{aligned}\pi_r^j(r^j) &= \frac{dq_0^j}{dr^j} \left[\frac{dq_1^j}{dq_0^j} (x_1 + x_{-1}) + (x_0 + x_{-1}) \right] \\ &= \frac{dq_0^j}{dr^j} \left[-\frac{x_1 + x_{-1}}{r^j} + (x_0 + x_{-1}) \right].\end{aligned}$$

As $\frac{dq_0^j}{dr^j} \leq 0$, we find that π^j is monotonically increasing in r^j for $r^j < R^* = \frac{x_1 + x_{-1}}{x_0 + x_{-1}}$, $\pi_r^j(R^*) = 0$, and π^j is monotonically decreasing for $r^j > R^*$. Hence, $\pi^j(r^j)$ is quasiconcave in r^j . ■

Let us now focus on the bank's constrained optimization problem. As is known from the literature on countervailing incentives—see Laffont and Martimort (2002) for the case with two types—we check whether or not the IC constraint is actually binding.

First, if $f(R^*)(\pi^H(R^*) - \tau^H) \leq \pi^L(R^*) - \tau^L$, IC is not an issue and the main text explains that R^* can be implemented.

The IC constraint is binding in the efficient outcome if

$$f(R^*)(\pi^H(R^*) - \tau^H) > \pi^L(R^*) - \tau^L. \quad (\text{A2})$$

Given contract offers $r^H = r^L = R^*$, L accepts the H contract. We proceed by assuming that (A2) holds and characterize the equilibrium for this case.

Taking into account that the low type's IC binds, we rewrite optimization problem (16) as

$$\max_{r^L, u^H, r^H} s^L(f(r^H)u^H, u_b^L)(\pi^L(r^L) - f(r^H)u^H) + s^H(u^H, u_b^H)(\pi^H(r^H) - u^H). \quad (\text{A3})$$

The first-order condition for r^L implies that $r^L = R^*$, the L contract is not distorted ("no distortion at the top"), as is to be expected. The first-order conditions for u^H and r^H can be written as

$$f(r^H) \frac{\phi}{2\tau^L} (\pi^L(R^*) - u^H f(r^H) - \tau^L) + \frac{1-\phi}{2\tau^H} (\pi^H(r^H) - u^H - \tau^H) = 0 \quad (U^{uc})$$

$$u^H f'(r^H) \frac{\phi}{2\tau^L} (\pi^L(R^*) - u^H f(r^H) - \tau^L) + \frac{1-\phi}{2} \pi_r^H(r^H) = 0. \quad (U^{rc})$$

The solutions to these first-order conditions correspond to two curves in (r^H, u^H) space. Denoting the curves with capital U , we refer to these curves as the utility curve $U^{uc}(r^H)$ and the risk curve $U^{rc}(r^H)$, resp. Note that these curves are continuous functions of r^H .

It will be convenient to also introduce the IC curve, which measures (as a function of r^H) H 's utility at which L is indifferent between his first-best contract and the H contract. This curve is defined as

$$U^{ic}(r^H) = \frac{\pi^L(R^*) - \tau^L}{f(r^H)}. \quad (U^{ic})$$

At all points (u^H, r^H) with $u^H \geq U^{ic}(r^H)$, L 's IC constraint is binding—which we assume to be the case.

An equilibrium is a pair u^H, r^H that simultaneously solves both first-order equations (U^{uc}) and (U^{rc}) , and therefore corresponds to an intersection of the risk and the utility curves, $U^{uc}(r^H) = U^{rc}(r^H)$. This is illustrated in Figure A1.

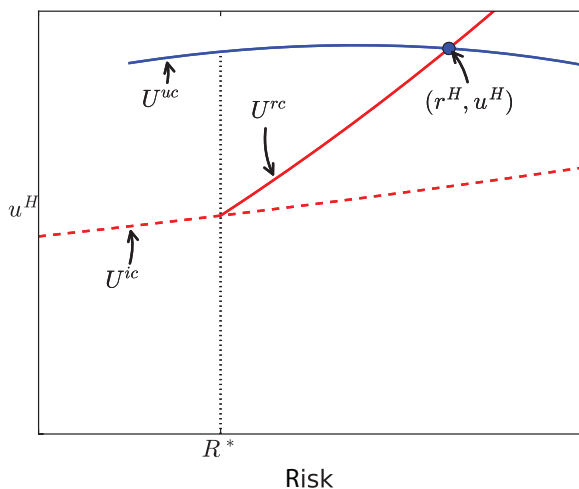
We use the following lemma below.

Lemma 3. With the optimal R^* —defined in equation (2)—we have

- (i) $U^{rc}(R^*) = U^{ic}(R^*)$
- (ii) $U^{rc}(r^H) > U^{ic}(r^H)$ if and only if $r^H > R^*$
- (iii) $U^{uc}(R^*) > U^{ic}(R^*)$.

FIGURE A1

EQUILIBRIUM IS AT THE INTERSECTION OF THE RISK AND UTILITY CURVES. [Color figure can be viewed at wileyonlinelibrary.com]



The lemma states that at the optimal R^* the risk curve intersects the IC curve, while the utility curve lies above it. This shows that if there is an equilibrium at finite $r^H > R^*$ —characterized by an intersection of both curves—the risk curve $U^{rc}(r^H)$ will cross the utility curve from below. We use this property when doing comparative statics in Proposition 2.

Proof of Lemma 3. When inserting $u^H = U^{ic}(R^*)$ in the risk curve equation (U^{rc}), the first term vanishes and we are left with $\pi_r^H(r^H) = 0$, which is indeed solved by $r^H = R^*$. This proves (i). For $r^H > R^*$, $\pi_r^H(r^H) < 0$ and the first term in equation (U^{rc}) has to be positive. Because $f'(r^H) < 0$, this implies that $U^{rc}(r^H)f(r^H) > \pi^L(R^*) - \tau^L = U^{ic}(r^H)f(r^H)$. Similarly, $r^H < R^*$ leads to $U^{rc}(r^H) < U^{ic}(r^H)$. This proves (ii). Finally, for the utility curve, assume (iii) does not hold, so $U^{uc}(R^*) \leq U^{ic}(R^*)$. Then, by the definition of the utility curve, (U^{uc}), we would have that $\pi^H(R^*) - U^{uc}(R^*) - \tau^H \leq 0$, or $\pi^H(R^*) - \tau^H \leq U^{uc}(R^*) \leq U^{ic}(R^*)$. However, this conflicts with our assumption (A2) that at R^* , IC does not hold. So, (iii) must hold. ■

It follows from (A2) that the intersection of the risk curve and the utility curve must lie beyond the privately optimal value R^* . To see this, suppose that $r^H < R^*$ would be an intersection of U^{uc} and U^{rc} . Then u^H lies below U^{ic} and the L trader's IC constraint does not bind. Thus, there is no reason to distort r^H and R^* can be implemented. However, this contradicts (A2).

Finally, the sufficient condition for existence of equilibrium (Assumption 5) is equivalent to $U^{uc}(\bar{r}^H) = U^{ic}(\bar{r}^H)$, as can be verified by setting $u^H f(\bar{r}^H) = \pi^L(R^*) - \tau^L$ in equation (U^{uc}). By Lemma 3 (i) and (iii), the risk curve is below the utility curve at $r^H = R^*$, whereas by (ii), the risk curve is above the IC curve $U^{ic}(r^H)$ for all $r^H > R^*$. If the utility curve $U^{uc}(r^H)$ crosses the IC curve at \bar{r}^H , it must have intersected the risk curve at least once at some $r^H \in (R^*, \bar{r}^H)$. This point of intersection corresponds with a symmetric equilibrium. ■

Proof of Proposition 2. If there is only one intersection of the curves U^{uc} and U^{rc} , the latter intersects the former from below—as illustrated in Figure A1.

However, we cannot exclude that multiple intersections of curves U^{uc} and U^{rc} exist. If there are multiple intersections, we assume that $\pi^H(r^H)$ is concave in r^H —as indicated in the main text. Then, the risk curve is everywhere upward sloping:

$$\frac{dU^{rc}}{dr^H} = -\frac{u^H f''(r^H)(\pi^L(R^*) - u^H f(r^H) - \tau^L) - (u^H)^2 f'(r^H)^2 + \pi_{rr}^H(r^H)}{f'(r^H)(\pi^L(R^*) - 2u^H f(r^H) - \tau^L)} > 0, \quad (\text{A4})$$

because $f'(r^H) < 0$ by Assumption 2; $f''(r^H) \geq 0$ by Assumption 3; $\pi^L(R^*) - 2u^H f(r^H) - \tau^L < \pi^L(R^*) - u^H f(r^H) - \tau^L < 0$ by equation (U^{rc}); and $\pi_{rr}^H < 0$ by assumption. However, the utility curve is not necessarily monotonically decreasing.

If there are multiple intersections, we focus on the one with lowest r^H . The following lemma demonstrates that this lowest- r^H equilibrium is the one that is preferred by both banks, as it maximizes total profits. ■

Lemma 4. If there are multiple equilibria, and $\pi^H(r^H)$ is concave in r^H for $r^H > R^*$, total firm profits are maximized at the equilibrium with lowest r^H .

Proof of Lemma 4. Total bank profits in any symmetric equilibrium (u^H, r^H) are given by

$$\Pi^{tot}(u^H, r^H) = \phi(\pi^L(R^*) - u^H f(r^H)) + (1 - \phi)(\pi^H(r^H) - u^H).$$

We show that these profits $\Pi^{tot}(u^H, r^H)$ are decreasing as one moves along the risk curve $U^{rc}(r^H)$ to higher r^H , that is, $\frac{d\Pi^{tot}}{dr^H}(U^{rc}(r^H), r^H) < 0$. Because any symmetric equilibrium (u^H, r^H) should lie on the risk curve, this will prove the lemma.

When a bank sets u^H , there is the individual bank benefit of increasing the share of profitable H traders. This disappears in Π^{tot} and hence, the negative effect of increasing utility for both L and H traders dominates. A decrease in u^H (here via a reduction in r^H along the U^{rc} curve) always raises Π^{tot} . As $U^{rc}(r^H)$ increases monotonically with r^H , the firms' profits from high-type traders unambiguously increase with decreasing r^H . However, this is not necessarily the case for the contribution from low types, as $u^L = u^H f(r^H)$ may decrease with r^H :

$$\frac{d(U^{rc} f)}{dr^H} = -\frac{u^H f''(r^H)(\pi^L(R^*) - u^H f(r^H) - \tau^L) + \pi_{rr}^H(r^H)}{f'(r^H)(\pi^L(R^*) - 2u^H f(r^H) - \tau^L)} f(r^H) + \frac{u^H f'(r^H)(\pi^L(R^*) - u^H f(r^H) - \tau^L)}{\pi^L(R^*) - 2u^H f(r^H) - \tau^L}. \quad (A5)$$

The first term is positive, but the second one is negative and the net result may be negative. The term $-\phi u^H f(r^H)$ in the profit function may therefore create a positive contribution to the derivative of total profits, Π^{tot} . We can see, nevertheless, that the offending positive term in the change in total profits, is always outweighed by the negative contribution from the high types:

$$(1 - \phi)\pi_r^H(r^H) = -u^H f'(r^H)\phi \frac{\pi^L(R^*) - u^H f(r^H) - \tau^L}{\tau^L},$$

which follows from the equation for the risk curve (U^{rc}). Comparison with the second term in (A5) makes clear that their net contribution to $\frac{d\Pi^{tot}}{dr^H}(U^{rc}(r^H), r^H)$ is again negative,

$$-\phi \frac{u^H f'(r^H)(\pi^L(R^*) - u^H f(r^H) - \tau^L)}{\pi^L(R^*) - 2u^H f(r^H) - \tau^L} - u^H f'(r^H)\phi \frac{\pi^L(R^*) - u^H f(r^H) - \tau^L}{\tau^L} < 0,$$

provided that

$$\pi^L(R^*) - 2u^H f(r^H) < 0.$$

However, as $u^H f(r^H) > \pi^L(R^*) - \tau^L = u^*$ (as IC is binding), we have

$$\pi^L(R^*) - 2u^H f(r^H) < \tau^L - u^H f(r^H) < \tau^L - u^* < 0,$$

where the last inequality follows from our Assumption of full market coverage, Assumption 1, $\tau^L - u^* < -\bar{u}^L < 0$. ■

By Lemma 3, the equilibrium corresponds to an intersection of the risk and utility curves where the risk curve intersects the utility curve from below. Only the utility curve depends on competition τ^H . It is straightforward to verify from the definition of the utility curve (U^{uc}) that

$$\left. \frac{dU^{uc}}{d\tau^H} \right|_{r^H} < 0.$$

Hence, for any given r^H , a decrease in τ^H causes the utility curve to shift upward. As a result, the intersection shifts to the right, to higher r^H . ■

Proof of Proposition 3. Total welfare is the sum of profits and trader utilities. As we have full coverage, both banks share the entire market for traders, and wages are only transfers which do not affect total welfare. Hence, bringing the cap closer to the first-best level R^* increases total welfare.

If the constraint binds and both banks set $r^H = \bar{R}$, the first-order conditions for u^H yield a symmetric equilibrium

$$u^H = \frac{\pi^H(\bar{R}) - \tau^H + f(\bar{R})(\pi^L(R^*) - \tau^L)}{1 + f(\bar{R})^2},$$

and $u^L = f(\bar{R})u^H$. As f and π^H are decreasing in \bar{R} , the derivative of u^L is always negative. A tighter cap then increases low-type traders' utilities. To see that the effect on high-type utility is ambiguous, let us consider the case where $\pi^L(R^*) - \tau^L$ is negligible compared to $\pi^H(\bar{R}) - \tau^H$, so that only the first term matters. It is then straightforward to see that if π^H is relatively flat, the decrease in f with \bar{R} dominates to increase u^H with \bar{R} . Also, vice versa, if f is relatively flat, the profit effect will dominate and u^H decreases with \bar{R} .

In the same example where $\pi^L - \tau^L$ is negligible, total trader utility is

$$u^H + u^L \sim \frac{1 + f(\bar{R})}{1 + f(\bar{R})^2} (\pi^H(\bar{R}) - \tau^H),$$

which for slowly varying π^H has a derivative the sign of which depends on the magnitude of $f(\bar{R})$. Because bank profits, for slowly varying π^H , change negatively with trader rents, also the derivative of profits can have either sign. ■

Appendix B

In this appendix, to verify that the symmetric solution to the first-order equations is an equilibrium, we first find sufficient conditions that deviations involving exclusion of either type are not profitable. Then, we check for sufficient conditions so that cornering the market for some type is not profitable either.

Lemma 5 (excluding the low types). For the proportion of low types, ϕ , sufficiently high, exclusion of low types is not a profitable deviation.

Proof. Denoting the rival's symmetric solution contracts by (\hat{u}^H, \hat{r}^H) and (\hat{u}^L, \hat{r}^L) , with $\hat{r}^L = R^*$ and $\hat{u}^L = \hat{u}^H f(\hat{r}^H)$, we explore a potential deviation (u^H, r^H) that attracts some high types but excludes the low types. This implies that

$$u^H > \hat{u}^H + \tau^H, \quad u^H f(r^H) \leq \hat{u}^H f(\hat{r}^H) - \tau^L.$$

We now ask whether adding a contract for the low types, (u^L, R^*) , increases profits for this potential deviation. Such a profitable contract exists if there is a u^L such that

$$u^L > \hat{u}^H f(\hat{r}^H) - \tau^L, \quad \text{and } \pi^L(R^*) - u^L > 0,$$

or

$$\pi^L(R^*) > \hat{u}^H f(\hat{r}^H) - \tau^L.$$

Now note that from the first-order conditions for \hat{u}^H , (equation U^{uc}), this is guaranteed as long as the proportion of low types ϕ is sufficiently large. In that case, $\pi^L(R^*) - \hat{u}^H f(\hat{r}^H) - \tau^L$ can be arbitrarily small (negative), so that $\pi^L(R^*) - \hat{u}^H f(\hat{r}^H) + \tau^L$ is positive. ■

Lemma 6 (excluding the high types). Excluding the high types will not be a profitable deviation if

$$\pi^L(R^*) - 2\tau^L > f(R^*)(\pi^H(R^*) - 2\tau^H).$$

Proof. Suppose we only have a contract for the low types, $u^L \geq \hat{u}^L - \tau^L$, that does not attract any high types, $u^L < \hat{u}^H - \tau^H$. We will show that we can then find a profitable and incentive-compatible contract (u^H, r^H) that attracts some high types as well. This will be the case for

$$u^H f(r^H) \leq u^L, \quad u^H > \hat{u}^H - \tau^H, \quad \text{and } \pi^H(r^H) - u^H > 0.$$

Let us take a high-type contract with first-best bonus ratio R^* , and u^H such that incentive compatibility holds,

$$u^H = \frac{u^L}{f(R^*)}.$$

Because $u^L > \hat{u}^L - \tau^L$, we will certainly attract high types if

$$\hat{u}^L - \tau^L > f(R^*)(\hat{u}^H - \tau^H).$$

As $\hat{u} > \pi^L(R^*) - \tau^L$, and $\hat{u}^H < \pi^H(\hat{r}^H) - \tau^H$, a sufficient condition for this to hold is

$$\pi^L(R^*) - 2\tau^L > f(R^*)(\pi^H(R^*) - 2\tau^H).$$

Next, we need to verify that this contract leads to positive profits. This requires

$$\frac{u}{f(R^*)} < \pi^H(R^*).$$

Either this holds, or, if it does not, we can alternatively pick a contract $u^H = \pi^H(R^*) - \epsilon$, $r^H = R^*$ which in that case satisfies incentive compatibility, attracts high types, and is profitable. ■

Lemma 7 (cornering). Cornering will not be a profitable deviation if the fraction of low types ϕ is large enough, and if

$$\tau^L - \tau^H < \frac{1}{2} \tau^H (1 - f(R^*)).$$

Proof. Cornering happens if either $u^H > \hat{u}^H + \tau^H$, or $u^L > \hat{u}^L + \tau^L$, or both. We can rule out the last alternative, as we could then always jointly lower offered utilities such that incentive compatibility remains satisfied. Consider then, cornering on the low-type market only. So, assume that we have contracts with

$$u^H \leq \hat{u}^H + \tau^H, \text{ and } u^L > \hat{u}^L + \tau^L.$$

We will be able to reduce u^L unless incentive compatibility binds, so that $u^L = u^H f(r^H)$. Now, consider the first-order conditions for u^H ,

$$\phi f(r^H) + (1 - \phi)s^H - \frac{(1 - \phi)(\pi^H(r^H) - u^H)}{2\tau^H} = 0,$$

where $s^H \leq 1$ is the high-type market share. Provided that $f(r^H)$ is bounded away from zero, if the fraction of low types ϕ is high, this cannot be satisfied for $0 \leq s^H \leq 1$ and $u^H \leq \pi^H(r^H)$.

Next, suppose we have cornering for the high types, $u^H > \hat{u}^H + \tau^H$, while $u^L \leq \hat{u}^L + \tau^L$. We can then profitably reduce u^H unless incentive compatibility for the high types binds, $u^H = u^L$. In that case, we require that both

$$u^L > \hat{u}^H + \tau^H, \text{ and } u^L \leq \hat{u}^H f(\hat{r}^H) + \tau^L,$$

which cannot hold if

$$\hat{u}^H + \tau^H > \hat{u}^H f(\hat{r}^H) + \tau^L.$$

A sufficient condition for that inequality to hold is

$$\tau^L - \tau^H < \frac{1}{2}\tau^H(1 - f(R^*)) < \hat{u}^H(1 - f(\hat{r}^H)),$$

as $\hat{u}^H > \frac{1}{2}\tau^H$ (full coverage) and $\hat{r}^H > R^*$. ■

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